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Spike Traits and Characteristics of Durum and Bread Wheat Genotypes at Different Growth and Developmental Stages under Water Deficit Conditions

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Abstract: Drought is an abiotic stress affecting the growth and development in plants and its negative effects during the vegetative and reproductive phases of growth causes different changes in the spike characteristics and traits in durum and bread wheat. A study was carried out to compare and evaluate these differences in spike traits in durum and bread wheat genotypes under different irrigation regimes. The experiments were laid out in split-plot arrangement based on a complete randomized block design with three replications at the Mashhad research stations of the Agricultural and Natural Resource Research Center, Iran. Irrigation regimes were considered as the main plots and included four levels, Subplots were assigned to four durum-promising lines and a bread wheat cultivar. The results indicated that the spikelets spike^{-1}, potential florets spike^{-1}, spike length, spike dry weight, spike partitioning coefficient and spike harvest index significantly decreased under water deficit during floral initiation to anthesis stage. In addition to this, the bread wheat cultivar (Chamran) showed the highest values for spikelets spike^{-1}, spike length, spike dry weight, spike partitioning coefficient and spike harvest index compared to durum wheat genotypes. However, a durum wheat genotype (RASCON_37/BEJAH_7) also exhibited higher values amongst the durum wheat genotypes. There were significant correlations among spike traits with the strongest association shown between spike partitioning coefficient and spike harvest index. Based on the results, any water limitation during the floral initiation to the anthesis stage have been caused negative effects on spike structure and its related traits

Key words: Anthesis, durum wheat, floral initiation, floret, spikelet, water deficit

INTRODUCTION

Water is the single most important factor determining crop yield and its limitation can change the ecological and physiological responses of plants during their different growth and development stages. Hence environmental stresses particularly water deficit can cause different changes in spike characteristics and its related reproductive traits, which are important organs in crop production and also yield and yield components (Casati, P. and V. Walbot, 2004; Canadian Food Inspection Agency, 2006; Passioura, J.B., 2007). In addition, Rahman *et al* (1977) found a positive correlation between the number of spikelets per spike and the length of the vegetative phase. With regard to different responses of the spike and spike traits to water deficit, many researchers have reported that water limitation at different growth and development stages affected the number of total and fertile spikelets per spike and florets per spikelet (Casati, P. and V. Walbot, 2004; Blum, A. and Y. Pnuel, 1990; Saini, H.S. and M.E.Westgate, 2000; Saini, H.S. and M.E.Westgate, 2000). On the other hand, variations in these traits were remarkably associated with changes in final grain yield (Simane, _ B., P.C. Struik, 1993; Khazaei. H., 2002; Benmoussa, M and A. Achouch, 2005). Results from Zhang and Oweis (1999) revealed that the first susceptible stage to drought stress was happened during the terminal spikelets and booting stages, whereas the second susceptible stage was between the booting stage and anthesis. They also showed that the spikelets and florets were differentiated at the terminal spikelets stage. Blum and Pnuel (1990) reported that water limitation during the terminal spikelets to booting stage affected yield and yield components. Water deficit at this stage, considerably decreased the number of spikelets per spike. The spike length reportedly showed stability under different conditions. However, the findings of Iqbal *et al*. (1999) on durum wheat indicated that the highest reduction in spike length under water deficit conditions was at the flowering stage. The objective of the present study was to determine the effects of water deficit on spike traits

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in durum and bread wheat genotypes during different growth and developmental stages. In addition to this, the relationship between the different spikes traits determined were studied.

MATERIALS AND METHODS

The study was conducted during the 2007-2008 growing season at the Khorasan-e- Razavi Agricultural and Natural Resource Research Center, Iran. The field experiments were laid out in Mashhad (36°, 13′ N latitude and 59°, 40′ E, elevation 985 m) research stations in a split-plot arrangement based on a complete randomized block design with three replications. Irrigation regimes were considered as the main-plots and included four levels, namely: I1, optimum irrigation; I2, water limitation from one-leaf to floral initiation stage; I3, water limitation from floral initiation to anthesis (including prevention of precipitation using a mobile rain shelter); I4, water limitation from anthesis to the late grain filling (including prevention of precipitation using a mobile rain shelter). Sub-plots were assigned to five wheat genotypes, four durum promising lines and a bread wheat cultivar. The soil texture at the experimental fields was clay loam. Soil pH and EC (ds m-1) was 8-8.1 and 1.7-2.2, respectively. Before sowing, the fields were fertilized with 50, 90, and 50kg NPK/ha. Additionally, 70 kg N was top- dressed and split into two applications. The seeds for the experiments were obtained from the elite durum yield trial (EDYT, 2006-2007) in the Seed and Plant Improvement Institute (SPII), Iran from among 20 studied genotypes, which were tested also under different osmotic stress conditions using PEG 6000 (Moayedi, A.A. and S.S. Barakbah, 2007; Boyce, A.N., 2009).

Table 1: List of durum and bread wheat genotypes used in study

Entry	Genotype	Pedigree	Plant Height (cm)	1000 KW (g)	Spike Length (mm)	Current commercial status
G1	Durum	HAI-OU_17/GREEN_38	85	50	61	No
G2	Durum	RASCON_37/BEJAH_7	87	54	62	No
G3	Bread	CHAMRAN	85	49	83	Yes
G4	Durum	RASCON_39/TILO_1	87	54	61	No
G5	Durum	GARAVITO3/RASCON37//GREEN8	83	53	62	No

Table 1 presents the genotype pedigree of the seeds used in the study. In the experimental design, each plot consisted of 12 rows, 3 meters in length spaced 20 cm apart. From this the sub-plot size was calculated as 7.2 m2 (12 x 3 x 0.2) and the seed density was 450 seed / m2 based on 1000-kernel weight. In order to compute spike traits, twenty plant stems (including leaves and spikes) were randomly selected from each plot at anthesis and physiological maturity stages. The samples were kept in an incubator for 3 days at 80°C and finally, the shoot and spike dry weight, the number of spikelets per spike, the number of total and potential florets per spike, and also the spike length were accurately measured in laboratory. In addition, the spike partioning coefficient (SPC) and spike harvest index (SHI) were calculated according to Donaldson (Donalson, E., 1996; Robertson, M.J. and F. Giunta, 1994) as follow:

SPC % = (SPKDWa / DMA) * 100

SHI % = (SPKDWa / DMM) * 100

Where, SPKDWa is spike dry weight at anthesis stage, DMA and DMM are above ground dry matter at anthesis and physiological maturity stages, respectively. Correlation coefficients among spike traits were computed using the SPSS software package. In conclusion, the data were statistically analyzed by MSTAT-C packages and comparative analyses of the means were performed by Duncan's Multiple Range Test ($P < 0.05$ and $P < 0.01$).

RESULTS AND DISCUSSION

Number of Spikelets per Spike:

Analysis of variance as shown in Table 2 revealed that effect of irrigation regime and interaction effect of the irrigation regime × genotype were significant ($P < 0.05$) for the number of spikelets spike^{-1}(SPKE),while genotypic effects was highly significant ($P < 0.01$).

The highest SPKE was observed in the I2 irrigation treatment, which was affected by water limitation from the one-leaf to floral initiation stage, while the lowest SPKE value belonged to the I3 irrigation treatment (water limitation from the floral initiation to anthesis). However, there were no significant differences between optimum irrigation (I1) with I2 and I4 for SPKE. Therefore, the most susceptible stage to drought stress was during floral initiation to anthesis, which was similar of the Blum and Pnuel (1990) reports. They revealed that water deficit between the terminal spikelets and the boot stage decreased the spikelet number per spike remarkably (Table 3). As shown in Table 4, the response of the spikelets was different among durum and bread wheat genotypes. Bread wheat genotype (G3) exhibited the maximum value (16 SPKE), whereas G5 (durum wheat) showed the minimum value (14 SPKE) among the five studied genotypes. However, there was no significant difference between G3 and G2.

Table 2: Analysis of variance (ANOVA) for number of spikelets spike^{-1} (SPKE), number of total florets (NTF), number of potential florets (NPF), spike length (SPKL), spike dry weight (SPKDW), day to heading (DH), spike partitioning coefficient (SPC), spike harvest index (SHI) in durum and bread wheat genotypes under different irrigation regimes.

		Mean square (MS)							
Source of variations	df	SPKE	NTF	NPF	SPKL	SPKDW	DH	SPC	SHI
Replication	2	0.2	11.5	3.3	29.1	15.39.4	6.21		1.95
Irrigation (I)	3	1.8^{*}	68.2^{ns}	96.4^{**}	66.1^{*}	10803.1^{**}	93.2^{*}	64.3^{**}	34.5^{**}
Error	6	1.6	38.3	9.7	12.6	20.5	17.2		0.65
Genotype(G)	4	7.7^{**}	684.8^{**}	227.9^{**}	1728.2^{**}	2522.5^{**}	33.2^{*}	15.8^{**}	15.4^{**}
I×G	12	1.4^{*}	112.9^{**}	47.4^{*}	38.9^{**}	97.4^{ns}	3.9^{ns}	3.6^{**}	4.2^{**}
Error	32	0.7	17.23	29.7	12.6	56.11	10.2	0.98	0.62
CV %	-	5. 4	5. 05	10. 21	5. 2	6. 40	4.73	10.7	10.97

*Significant difference at $P < 0.05$ **significant difference at $P < 0.01$ *ns*: no significant

Table 3: Response of spikelets spike^{-1} (SPKE), number of potential florets spike^{-1} (NPF), spike length (SPKL), spike dry weight (SPKDW), , spike partitioning coefficient (SPC), day to heading (DH) and spike harvest index (SHI) and leaf area index (LAI at terminal spikelets phase) under different irrigation regimes

Traits	SPKE	NPF	SPKL (mm)	SPKDW (mg)	SPC	DH	SHI	LAI
Irrigation regime								
I1	15.13 ab	54.9 ab	67.7 ab	146.6 a	10.0 a	118a	7.9a	2.2 a
I2	15.17 a	51.9 ab	69.6 a	115.2 c	9.2 b	113b	7.5 a	2.1bc
I3	14.43 c	50.8 b	65.3 b	81.9 d	6.4 c	118a	4.9 b	1.9c
I4	15.01 b	56.1 a	69.9 a	124.1 b	10.2 a	118a	8.4 a	2.2 a
LSD	0.16	4.22	3.18	6.13	1.54	3.71	1.1	0.19
Sx	0.02	0.80	0.92	1.17	0.29	1.07	0.2	0.07

Column sharing the same letters indicates no significant differences

Number of Potential and Total Florets per Spike:

Analysis of variance revealed that, apart from the number of total floret (NTF), which was not significantly different under irrigation regime condition, both the potential (NPF) and total florets traits were highly significant due to genotype and their interaction effects (Table 2). Besides, the NPF was also significantly affected under water deficit conditions. The response of the NPF under different irrigation regimes indicated that the highest negative effect of water limitation was made during the floral initiation to anthesis stage (I3), while the lowest negative effect belonged to the I4 treatment (Table 3). With regard to fertility of the florets before the anthesis stage in wheat, water limitation during floral initiation to anthesis caused the highest reduction of NPF compared to other irrigation regimes. Conversely, water deficit after anthesis (I4) caused the lowest negative effect on the NPF (Table 3). Regarding to the significant effect of genotype on the NTF and NPF as shown in Table 2, the highest NTF and NPF were produced by G1 whilst the lowest values for both traits belonged to the G5 genotype. Generally, there was a similar trend concerning the NTF and NPF among the different genotypes (Table 4).

Table 4: Response of spikelets spike^{-1} (SPKE), number of total florets spike-1 (NTF) number of potential florets spike^{-1} (NPF), spike length (SPKL), spike dry weight (SPKDW), spike partitioning coefficient (SPC) , day to heading (DH) and spike harvest index (SHI) in different durum and bread wheat genotypes

Traits	SPKE	NTF	NPF	SPKL (mm)	SPKDW (mg)	SPC	DH	SHI
Genotype								
G1	14.7 bc	92.8 a	58.8 a	64.3 b	116.9 b	8.12 c	118ab	6.79b
G2	15.6 ab	86.1 b	57.0 ab	61.4 b	121.2 b	9.92ab	119 a	8.12a
G3	16.2 a	812 c	51.1 bc	89.5 a	136.2 a	10.81a	116 b	8.47a
G4	14.6 c	77.5cd	51.8 bc	62.3 b	114.7 b	8.97bc	116 b	7.01b
G5	14.2 c	73.4 d	48.3 c	63.0 b	95.8 c	8.23 c	115 b	5.61c
LSD value	0.91	6.64	6.09	3.97	8.37	1.11	2.65	0.88
Sx	0.23	0.01	1.57	1.02	2.16	0.28	0.92	0.23

Column sharing the same letters indicates no significant differences

Spike Length:

As shown in Table 2, apart from the irrigation regime, which was significantly ($P < 0.05$) for spike length, effect of genotype and interaction effects were highly significant for this trait. Table 3 shows that spike length is affected by water limitation at the different growth and developmental stages. Similar to the NPF, the most susceptible stage to water deficit in durum and bread wheat genotypes was the I3 treatment. Hence, the lowest value for spike length (65 mm) was observed in I3 whereas the highest (70 mm) was seen under I4 treatment. However, there was no significant difference between the I4 and I2 treatments. With regard to genotypic effects, genotype G3 (bread wheat) exhibited a remarkable variation in spike length compared to the other studied genotypes (Table 4). However, there was no significant difference in spike length amongst the durum wheat genotypes (G1, G2, G4, and G5). Although spike length shows some stability under different conditions, the results of the present study demonstrated that it decreased significantly under water deficit during the floral initiation to anthesis period, which is congruent with the reports of Iqbal *et al.* (1999) on durum wheat and Ghodsi (2004) on bread wheat. Overall, the reduction of the spike length under water stress conditions causes a decrease in some of the spike traits. It can therefore cause some changes in the number of spikelets and florets per plant. For this reason, it is clear that the reduction of SPKE and NTF under I3 treatment, are strongly related to the decrease in spike length (Table 3).

Spike Dry Weight at Anthesis Stage (SPKDW):

Analysis of variance for spike dry weight (SPKDW) revealed that apart from the interaction effect of water deficit ×genotype, which was not significant for spike dry weight, water deficit and genotype effects were highly significant for this trait (Table 2). Fig.7 presents the significant effect of water deficit at different growth and development stages on SPKDW. It decreased remarkably under water deficit conditions compared to that under optimum irrigation. The highest reduction (66%) of the SPKDW compared to optimum irrigation was observed under I3 treatment, while the lowest reduction (17%) was seen under I4 treated plants (Table 3). It was found that water limitation during the floral initiation to anthesis stage (I3) severely decreased the SPKDW whereas the effect of water deficit at the earlier (I2) and later growth stages (I4) were comparatively milder which was concurred with finding of Robertson and Giunta (1994). They noted that water deficit treatments reduced spike biomass at anthesis to 58-94% of that in the optimum irrigation.

It seems that significant reduction in the leaf area index under I3 water deficit treatment compared to optimum irrigation had been decreased SPKDW (Table 3). With regard to formation of the spike structure during time range of the double ridge to anthesis, which is congruous on the I3 irrigation regime condition, thus any negative effect at this period causes similar impact on the spike traits. Fisher (2001) and Araus *et al.* (2003) revealed that reduction in the LAI under water stress decreases intercepted radiation and partitioning of the photosynthetic matter to spike. On the other hand, as to the spike structure formation during terminal spikelets to anthesis stage (Slafer, G.A. and E.M. Whitechurch, 2001), the results of the present study confirms that any unfavorable conditions during this period causes a sizable reduction in the spike dry weight value which concur with reports by Robertson and Giunta (1994) and also by Nazeri (2005).

Spike Partitioning Coefficient (SPC):

Spike partitioning coefficient is an important trait in durum and bread wheat growth as it shows the ratio of photosynthesis matter partitioned to form the spike. It is calculated based on the spike dry weight to shoot dry weight ratio at anthesis stage. Hence, it can increase with increasing spike dry weight value or reduce with increasing shoot dry weight (Blum, A., 1998). Analysis of variance (Table 2) revealed that water deficit, genotype effects and their interactions were highly significant for the spike-partitioning coefficient (SPC). Statistical differences among the irrigation regimes (Table 3) indicated that water limitation during the floral initiation to anthesis stage (I3) remarkably decreased the SPC, by about 45% compared to those under optimum irrigation, whilst there was no significant difference between the I1, I2 and I4 treatments. These results confirm the findings of Ghodsi (2004), Donalson (1996) and Robertson and Giunta (1994) . These researchers also reported that water deficit before anthesis decreased spike dry weight and the spike partitioning coefficient. However, it had little effect on the pattern of biomass partitioning to the spike and the proportion of anthesis biomass as spike. Thus, any negative effects during the terminal spikelet to anthesis period decreased these crucial spike traits. In addition, the genotype effects on the spike-partitioning coefficient were similar to that on spike dry weight trait described above (Table 4). The interaction effect of the water deficit × genotype on the SPC indicated that genotype G3 (bread wheat) gave the highest SPC under all the irrigation regimes except in the I4 treatment. The genotype G2 showed a higher value, compared to the other durum wheat genotypes under the I3 treatment, which is the crucial period for the SPC and SPKDW traits (Fig.1)

Spike Harvest Index (SHI):

Spike harvest index (SHI) is the spike dry weight (at anthesis) to total dry weight ratio at physiological maturity. It shows the proportion of mobilized dry matter to spike in a genotype (Donalson, E., 1996). Analysis of variance (Table 2) showed that water deficit, genotype effects and their interactions were highly significant for SHI. The results of present study demonstrated that the effects of water deficit and genotype on SHI were similar to that for spike dry weight and spike partitioning coefficient (Table 3). Thus, the lowest SHI value was produced under water deficit conditions during floral initiation to anthesis, a crucial period for this trait.

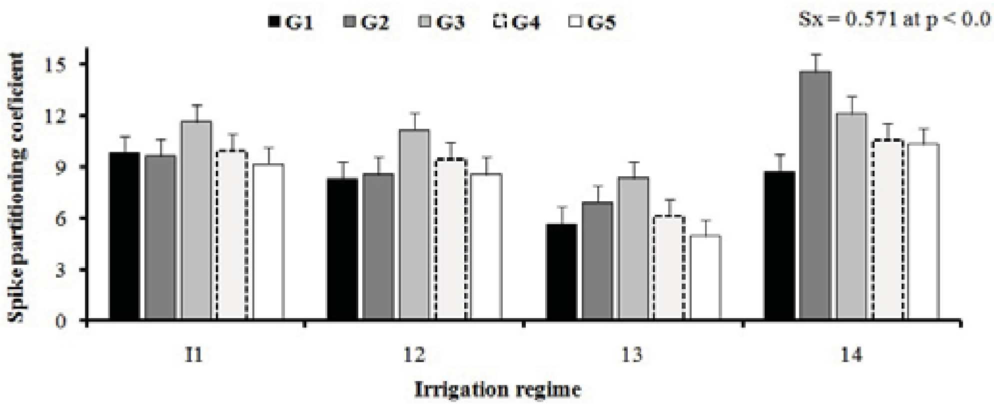

Fig. 1: Interaction effect of irrigation regime × genotype on spike partitioning coefficient Bars indicated standard deviations

Number of Days to Heading (DH):

As shown in Table 2 the analysis of variance revealed that irrigation regime and genotype effects were significant ($p < 0.05$) for the number of days to heading (DH). However, there were no significant differences between optimum irrigation (I1) with I3 and I4 treatments for this trait. Water limitation during one-leaf to floral initiation stage significantly decreased DH (Table 3). In other words, the negative effect of water deficit at the early growth and developmental stages can be effective in the reducing DH in the durum and bread wheat genotypes.

Correlation Studies:

As shown in Table 5, Pearson correlation coefficient showed the highest positive relationship between the SHI and SPC (r = 0.95), NPF and NTF (r = 0.88), SPKW and SHI (r = 0.78), SPKE and SHI (r = 0.68), SPKE and SPC (r = 0.63), SPKE and SPKL (r = 0.62), SPKE and SPKDW (r = 0.56), SPKDW and SPKL (r = 0.41), SPKL and SPC (r = 0.40), NPF and DH (r = 0.38), respectively. While, relationship between SPKL and NFT, SPC and DH, SHI and DH, NTF and GY, NPF and GY, SPC and GY were negative and no significant. With regard to the importance of the spike characteristics and traits related on final production and grain yield, there was a positive relationship between the grain yield of the genotypes in present study with SPKE, SPIKE LENGTH, SPKDW and DH whereas it was shown a negative association with NTF, NPF, SPC and SHI. Overall, variations in spike structure and traits were remarkably associated with changes in final grain yield, which confirms previous works by other researchers (Rahman, M.S., 1997; Simane, _ B., P.C. Struik, 1993; Khazaei. H., 2002; Benmoussa, M and A. Achouch, 2005).

Table 5: Pearson correlation coefficients for spikelets spike^{-1} (SPKE), number of total florets spike-1(NTF), number of potential florets spike^{-1} (NPF), spike length (SPKL), spike dry weight (SPKDW), day to heading (DH), spike partitioning coefficient (SPC), spike harvest index (SHI), spike harvest index (SHI) and grain yield (GY)

Traits	SPKE	NTF	NPF	SPKL	SPKDW	DH	SPC	SHI	GY
SPKE	1	0.34	0.35	0.62**	0.56**	0.009	0.63**	0.68**	0.097
NTF		1	0.88**	0.099	0.328	0.334	0.158	0.158	-0.091
NPF			1	-0.081	0.372	0.384*	0.308	0.368	-0.237
SPKL				1	0.409*	0.204	0.405*	0.375	0.106
SPKDW					1	0.130	0.77**	0.78**	0.145
DH						1	-0.043	-0.101	0.066
SPC							1	0.95**	-0.333
SHI								1	-0.139
GY									1

* Correlation is significant at the 0.05 level ** Correlation is significant at the 0.01 level

Conclusion:

Our studies have shown that water deficit conditions during growth and developmental stages brought about different effects on the spike structure and its related traits in durum and bread wheat. The results revealed that the SPKE, NPF, SPKL, SPDW, SPC, and SHI significantly decreased under water deficit condition during the floral initiation to anthesis stage. In addition, the Chamran bread wheat cultivar (G3), which was used as a drought tolerant cultivar in the present study, showed the highest values for the SPKE, spike length, SPKDW, SPC and SHI compared to the durum wheat genotypes. However, G2 durum wheat genotype (RASCON_37/BEJAH_7) also exhibited higher values among the durum wheat genotypes. Regarding to significant relationships among the spike traits, the strongest correlation was shown between the SHI and SPC. Additionally, there were positive relationships between grain yield with SPKE, spike length, SPKDW and DH, and finally spike dry weight. Overall, the results indicated that the most susceptible growth stage to water deficit for developing of the spike and its related traits is the floral initiation to anthesis stage, in durum and bread wheat genotypes. Therefore, any water limitation during this period causes a negative effect on the spike structure, its related traits and grain yield.

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REFERENCES

Araus, J.L., J. Bort, P. Steduto, D. Villegas and C. Royo, 2003. Breeding cereals for Mediterranean conditions: ecophysiological clues for biotechnology application. Annals of Applied Biology, 142: 129-141.

Benmoussa, M and A. Achouch, 2005. Effect of water stress on yield and its corposants of some cereals in Algeria. J. Central Eur. Agriculture, 6(4): 427-434.

Blum, A. and Y. Pnuel, 1990. Physiological attributes associated with drought resistance of wheat cultivars in a Mediterranean environment. Aust. J. Agric. Res., 41: 799-810.

Blum, A., 1998. Improving wheat grain filling under stress by stem reserve mobilization. Euphytica., 100: 77-83.

Boyce, A.N., S.S. Barakbah, A.A. Moayedi and M. Ghodsi, 2009. Effect of different osmotic stresses on percentage, rate and germination stress index in durum wheat genotypes. In the Proceedings of the EKSPO Inovasi, 13-15 January 2009, University of Malaya. Kuala Lumpur, Malaysia, pp: 27-28.

Casati, P. and V. Walbot, 2004. Rapid transcriptase responses of maize (*Zea mays*) to UV-B irradiated and shielded tissues. Genome Biol., 5: 16-28.

Canadian Food Inspection Agency, 2006. The biology of Triticum turgidum spp (durum wheat). A companion document to the assessment criteria for determining environmental safety of plant with novel traits. Plant Biosafety Office (PBO).

Donalson, E., 1996. Crop traits for water stress tolerance .American Jurnal of Alternative Agriculture, 11: 89-94.

Fisher, R.A., 2001. Selection traits for improving yield potential. In: Reynold, M.P., Oritz- Monasterio, J.I., and McNab, A.(eds). Application physiology in wheat breeding Mexico, D.F, CIMMYT, pp: 148-159.

Iqbal, M., K.I. Ahmad, M. Sadiq and M.Y. Ashraf, 1999. Yield and yield components of durum wheat as influenced by water stress at various growth stages. Pak. J. Biol., Sci., 2: 11-14.

Khazaei. H., 2002. Effect of drought stress on yield and physiological aspects of resistant and susceptible wheat cultivars and introducing the best drought resistance criteria. Ferdowsi. PhD thesis, University of Mashhad, Iran.

Moayedi, A.A. and S.S. Barakbah, 2007. Study on durum wheat genotypes at germination stage under different osmotic stress. In the Proceedings of the ISSAAS Congress, Agriculture is a Business, l2-14 December 2007, Metaka, Malaysia, pp: 23-24.

Nazeri, M., 2005. Study on response of triticale genotypes at water limited conditions at different developmental stages. PhD thesis, University of Tehran, Iran.

Passioura, J.B., 2007. The drought environment: physical, biological and agricultural perspectives. Journal of Experimental Botany, 58:113-117.

Rahman, M.S., J.H. Wilson and V. Aitken, 1977. Determination of spikelet number in wheat. II. Effect of varying light level on ear development. Austr. J. Agric. Res., 26: 575-581.

Robertson, M.J. and F. Giunta, 1994. Responses of spring wheat exposed to pre-anthesis water stress. Australian Journal of Agricultural Research., 45: 19-35.

Saini, H.S. and M.E.Westgate, 2000. Reproductive development in grain crops during drought. .Advances in agronomy, 68: 59-96.

Saini, H.S. and M.E.Westgate, 2000. Ecophysiological aspects of water deficit on growth & development of wheat cultivars. PhD thesis, University of Tehran, Iran.

Simane, B., P.C. Struik, M.Nachit and J.M. Peacock, 1993. Antigenic analysis of yield components and yield stability of durum wheat in water limited environments. Euphytica., 71: 211-219.

Slafer, G.A. and E.M. Whitechurch, 2001. Manipulation wheat development to improve adaptation. In: Reynold, M.P., J.I. Oritz Monasterio and McNab, A. (eds). Application physiology in wheat breading. Mexico, D.F, CIMMYT, pp: 160-170.

Zhang, H.P. and T. Oweis, 1999. Water yield relations and optimal irrigation cheduling of wheat in the Mediterranean region. Agric. Water Manua, 38: 195-211.